Transportation planning process for developing countries Great Beirut area as case study

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Every year the number of vehicles using roads all over the world increases alarmingly. Congestion is increasing and the road network is not keeping pace with the growth of traffic, and at the same time the construction of new roads is environmentally undesirable. This apparent impasse is to some extent due to a misconception of the real concept. The need is not for the provision of bigger and better roads to cope with more and more vehicles. The real objective is the modifying of the modal split. The people must be transported by more environment friendly transport system. Having redefined the concept, the problem changes into the need for a planning process that meets this concept. Comprehensive transport systems aim to optimize the use of different transport modes. The goals of this paper are to define the transportation planning process, construct a computer program that meets this process, and apply it on the Great Beirut Area (GBA). The paper aims also to show the economic and environmental gains that can be reached by applying such a process. Different scenarios are studied, one of which is the Authorized Master Plan of GBA. To perform the planning process, computer models were programed and applied on GBA. The program was used in building transportation models for trip attraction and generation, forecasting of future demand, trip distribution, trip assignment, network evaluation, and environmental impacts. The program is written using “Math-Cad 2001 Pro”.

تُستخدم شبكة المواصلات بشكل كثيف ومتزايد سنويا .إلا أن ما يتم من تجديد وصيانة لشبكات الطرق لا يتناسب مع حجم الازدياد في حركة النقل والمرور، وهو أيضا عمل غير مستحب بيئيًا. هذه الظاهرة هي إلى حد كبير نتيجة سوء فهم المشكلة الحقيقية .إن الحاجة ليست لطرق أفضل وأوسع كي تخدم حركة السير، وانما للتوزيع الصحيح بين النقل العام والخاص .عندما يفهم الهدف بشكل صحيح، تتحول المشكلة الى السعي وراء التخطيط الذي يتلاءم مع ذلك الهدف. إن الهدف الرئيسي من هذا البحث هو تعريف عملية تخطيط النقل وبناء نماذج علي الحاسب الآلي والتي تحقق هذه العملية ،مع تطبيق هذا البرنامج علي منطقة بيروت الكبري كحالة دراسة.وقد أثبت هذا البحث العديد من المكاسب البيئية والاقتصادية التي يمكن الحصول عليها بتطبيق عمليات تخطيط النقل بالدول النامية. ولتحقيق عملية التخطيط تم بناء نماذج علي الحاسب الآلي، وهذه النماذج تشمل المراحل المختلفة لعمليات التخطيط من تولد وانبثاق الرحلات، وتوزيعها علي الخلايا وعلي وسائل النقل المختلفة، ثم تخصيص هذه الرحلات علي شبكات النقل وتقييم هذه الشبكات، وكذلك دراسة التأثير البيئي الناتج من أنظمة النقل .ولقد تم برمجة هذا البرنامج باستعمال Math-Cad 2001 Pro ...

Keywords: Transportation models, Math-Cad 2001 pro, Assignment, Economic analysis

1. Introduction

Transport planning must be comprehensive, and based on financial realism. The roles of public transport, private car restraint, traffic management measures, and new road construction need to be fully integrated to derive the best use of the inevitably limited resources. A transport planning process may be developed as a complete package of projects and policies, conceived as a unified whole. It should be implemented in accordance with a carefully conceived, financially realistic, annual program, derived in turn from a longer program.

Transport planning process needs specific detail data, the lake of such data in developing countries makes the transport planner to search for simple transport models to adapt the available data in these countries. The purposes of this paper are to define the transportation planning process, construct a computer program that meets this process, and apply it on the Great Beirut Area (GBA) as a developing country.

This paper is divided into four major sections. The first section defines the transportation planning process. In the second section, a representation of the program T.P.P, a program that performs the planning process, is introduced. In the third section, models used for the T.P.P-program are identified. The fourth section represents an application of the program package on the GBA.

2. Transportation planning process

In urban areas, the medium-term planning of future transport systems is usually based on a transportation planning process. A modern transportation planning process is basically a computer-dependent mathematical process, founded on present-day observation, whereby future travel patterns can be predicted, in essence, the transportation planning process consists of:

• Surveying the present-day travel habits of people living and/or working in the specified area (data collection),

• Developing mathematical models which give details of the relationship between household structure, income, car ownership, and socio-economic data in the study area, and present-day travel patterns as surveyed. These models in their simplest form are basically:

1. Trip-end prediction: Determining how many trips leave a transport zone,
2. Trip distribution: Determining the destination of these trips
3. modal split: Determining the mode of travel,
4. Assignment: Determining the actual roads used.
5. Network evaluation: Determining the level of service of network links, and
6. Environmental assessment: Determining the environmental impact of the whole process.

•Using these Models, together with predicted values for future socio-economic data to predict future travel patterns.

•Comparing the merits of alternative transport systems to accommodate the predicted movements. This comparison may depend on economic, operational and environmental issues, as well as political aspects.

Fig. 1 illustrates the basic principles of the transportation planning process [1].

3. Program for Transportation planning process

The Transportation Planning Process (TPP) program is a computer program designed using MathCAD program (Math CAD 2001 professional). It consists of a set of modules that are used to perform many calculations needed through a transportation planning process. For each application, the input file is a group of tables that are ready for input data. The analysis is automatically done and the results are listed in output tables.

MathCAD is chosen as a programming language because it is a user-friendly program and it is able to perform many effective mathematical operations. It contains a programming facility with a simple programming language which can be easily applied on transportation models.

The planner must begin with the existing transportation and socio-economic data of the base year. The following are examples of the input data:

•Statistics about population and their distribution over the area of study,

•Statistics about employment and work places,

•Statistics about income and car Ownership,

•Travel demand at the base year (O/D matrix),

•Existing modal split of different transportation systems,

•Geometry of existing road network or design road network, and

•Characteristics of links (times, flows, speeds, capacity of roads).

Fig. 2 shows the structure of the TPP (program for Transportation Planning Process).

This program contains the following phases:

•Input of socio-economic data,

•Forecasting of socio-economic data,

•Trip generation and attraction models,

•Trip distribution,

•Distribution of trips on transport models (modal split),

•Assignment of trips on transport network,

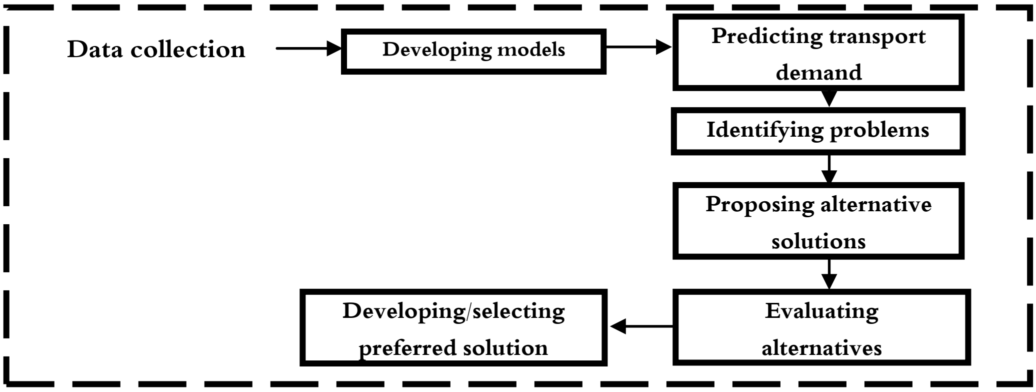

Fig. 1. The basic principles of the planning process.

•Determination of the level of service of links and network evaluation
• Environmental assessment; pollution and noise evaluation
• Selection of preferred solution.
Fig. 3 presents the main modules of the TPP.

4. Models used in TPP

TPP as a Transportation Planning Process uses mathematical models for the following program module:
• Forecasting of socio-economic data,
• Trip generation and attraction,
• Trip distribution,
• Modal split,
• Trip assignment,
• Evaluation of road network, and
• Environmental assessment.

Predicting the future socio-economic data in TPP program depends on the annual growth factor of the variable mathematical model, which can be determined from regression technique.

The TPP applies multi-linear regression analysis to get and apply the following trip generation models:

$$Q_i = a_0 + a_1 x_{1i} + a_2 x_{2i} + \ldots + a_n x_{ni} ,$$

$$Z_j = b_0 + b_1 x'_{1j} + b_2 x'_{2j} + \ldots + b_n x'_{nj} ,$$

where:
Q_i is the number of trips generated from zone i,
Z_j is the number of trips attracted from zone j,
a,b are the regression parameters,
x is the variable affecting trip generation, and
x' is the variable affecting trip attraction.

For GBA as a case study, the following regression models are derived:

$$Q_i = 5765 + 0.058\, X_{1i} + 1.642\, X_{2i} + 0.629\, X_{3i} + 53.85\, X_{4i} + 6.836\, X_{5i} + 6.36\, X_{6I},$$

$$Z_j = 1598 + 0.146\, Y_{1j} + 0.085\, Y_{2j} + 0.02\, Y_{3j} + 1.144\, Y_{4j} + 52.971\, Y_{5j},$$

where:
X_1 is the population number in zone i,
X_2 is the number of employees that live and work in zone i,
X_3 is the number of employees that live but don't work in zone i,
X_4 is the number of households having an average annual household income less than 4 million L.L.,
X_5 is the number of households having an average annual household income from 4 to 5 million L.L.,
X_6 is the number of households having an average annual household income from 13 to 30 million L.L.,
Y_1 is the workplaces occupied by residents of the zone j,
Y_2 is the workplaces occupied by non-residents of the zone j,
Y_3 is the number of educational places of zone j (primary, middle, and secondary),
Y_4 is the number of university educational places in zone j, and
Y_5: is the area of zone j.

The third module of TPP program uses the results of the first and second application to get the total generated and attracted trips in the target year, and then distributes these trips according to zones using the gravity model.

The gravity model gets its name from the fact that it is conceptually based on Newton's Law of gravitation, which states that the force of attraction between two bodies is directly proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them. The general form of gravity model is [2]:

$$F_{ij} = K_{ij} * Q_i * Z_j * W_{ij}^{-Y} ,$$

$$K_{ij} = 0.5\left(\frac{1}{\sum_{i=1}^{n} Q_i * W_{ij}^{-Y}} + \frac{1}{\sum_{j=1}^{n} Z_j * W_{ij}^{-Y}} \right),$$

where:

K_{ij} is the trip production balance factor,

W_{ij} is the travel resistance between zone i and zone j. It is considered to be the distances between the centroids of zones in GBA case study,

γ is the sensitivity factor of travel resistance,

Q_i is the trips generated from zone I,

Zj is the trips attracted to zone j, and

Fij is the number of trips from zone i to zone j.

The fourth module of the TPP program applies the following multi-nominal logic model to distribute the trips on transport models:

$$P(K) = \frac{e^{UK}}{\sum_{K=1}^{n} e^{UK}} ,$$

$$U_K = a_K + a1X1_K + a2X2_K + ... + anXn_K ,$$

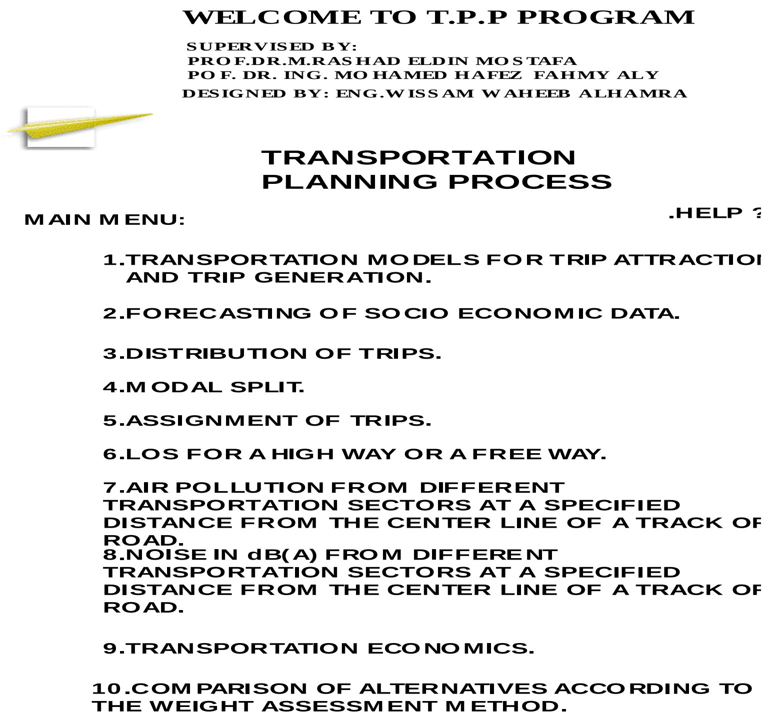

Fig. 2. The structure of the TPP – program (program for transportation planning process).

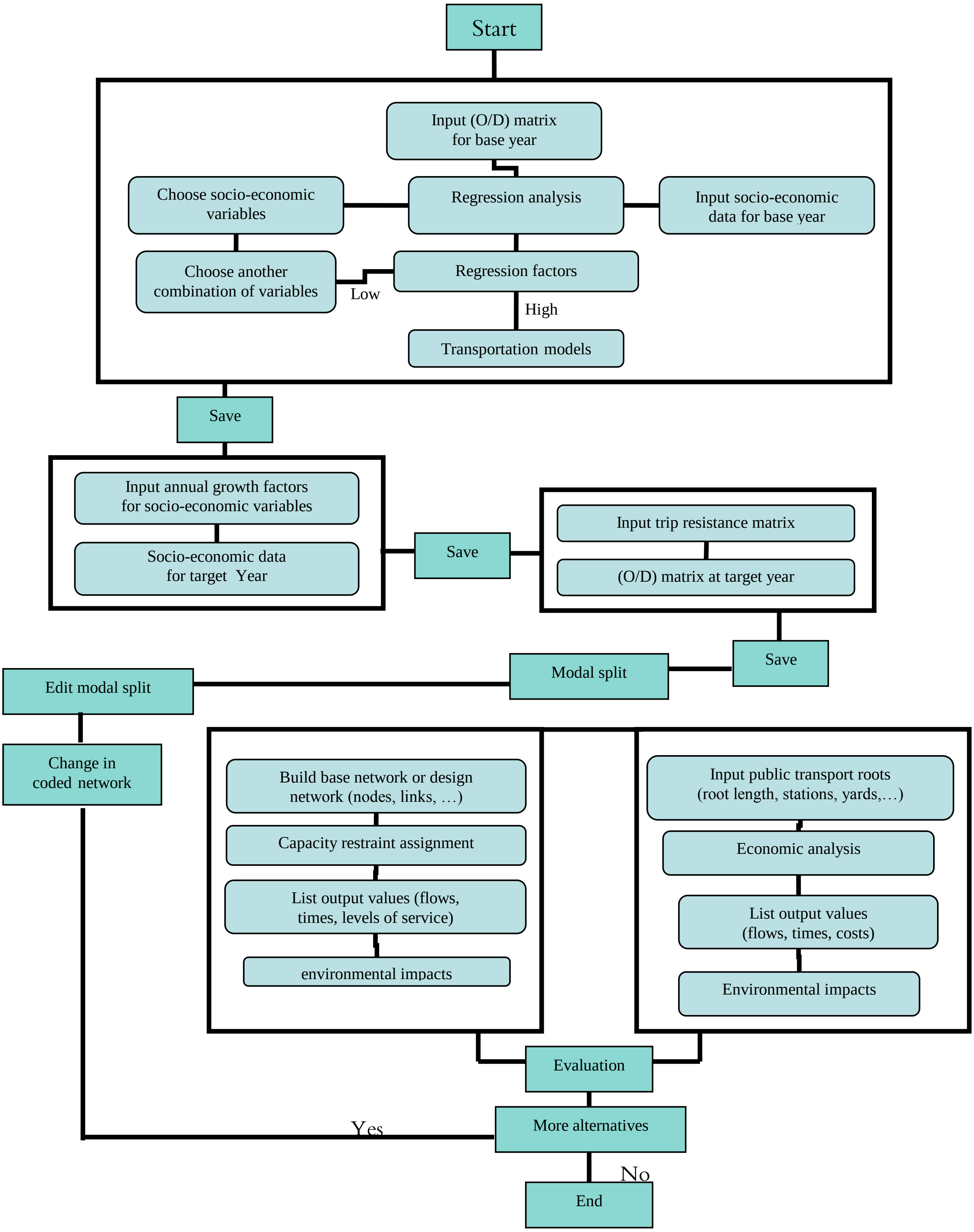

Fig. 3. The main modules of the TPP.

where:
$P(K)$ is the proportion of travelers that use transport mode K,
U_K is the utility of mode K,
a_K is the calibrated mode-specific-constant of mode K,and
X is the factors affecting the utility of mode K (such as trip cost, trip time, access time…).

Passenger car unit (*pcu/hr*) can be also transformed into passenger (*pass/hr*) according to the following model:

$$T_{ij} = F_{ij} \sum_{k=1}^{n} \frac{P_k * ocu_k}{eq.pcu_k} ,$$

where:
T_{ij} is the trips generated from zone i and attracted by zone j,
F_{ij} is the *pcu* generated from zone i and attracted by zone j,
P_i is the Percentage of *pcu* taken by mode K,
ocu_k is the occupancy of one unit of mode K, and
$eq.pcu_k$ is the number of equivalent *pcu* to one unit of mode K.

Trips are assigned in TPP -program according to the capacity restrained method. The capacity restrained model used in TPP is:

$$t_i := t_0 . \left[1 + X . \left(\frac{M}{C} \right)^4 \right],$$

Where:
t_i is the trip time after the assignment phase i,
t_0 is the trip time before the assignment phase i,
x is the rate of change of trip time,
M is the road occupancy (*pcu/hr*), and
C is the road capacity (*pcu/hr*).

The TPP program evaluates the road network by determining the level of service and delays of the road network and links. According to the type of network, the program has to use the suitable models:

1. For a multi-lane freeway, the TPP program applies the following model:

$$MSF_i = C_j * \left(\frac{v}{C} \right)_i ,$$

where:
MSF_i is the max service flow rate per lane for level of service i under ideal conditions (*pc/hr/lane*),
$\left(\frac{v}{C} \right)_i$ is the max volume-to-capacity ratio associated with level of service i, and
C_j is the capacity under ideal conditions for a free way with design speed j.

The concept of a maximum service flow rate provides an important mark for determining a highway's level of service. Some methods of converting the maximum service flow rate into an equivalent service flow rate are needed. Once this is achieved, the highest service flow rate at prevailing conditions for a given level of service (SF_i) can be related to the service flow rate obtained from actual vehicle counts (SF) to determine the highway's level of service. SF can be determined from the following model:

$$SF = \frac{V}{PHF} = V_{15} * 4 \text{ (from actual counts)},$$

V is the hourly volume,
PHF is the Peak hour factor,
V_{15} : 15 min. rate of flow.

The service flow rate for level of servive i can be determined in the TPP-program from the following model:

$$SF_i = C_j \left(v/C \right)_i * N * F_W * F_{HV} * F_P ,$$

where:
SF_i is the Service flow rate for level of service i under prevailing conditions for N directional lanes in *veh/hr*.
where:

$$F_{HV} = \frac{1}{1 + P_t(E_t - 1) + P_B(E_B - 1) + P_r(E_r - 1)},$$

where:
E_t is the equivalency factor for trucks,
E_B is the equivalency factor for Bus,
E_y is the equivalency factor for other recreational vehicles,
P_t is the percentage of trucks,
P_B is the percentage of buses,

P_y is the percentage of other recreational vehicles,
F_{HV} is the factor to adjust for the effect of non passenger car in the traffic stream,
F_P is the factor to adjust for the effect of non ideal driver populations (non regular travelers) or driver behavior,
F_W is the factor to adjust for the effect of less than ideal lane width and / or lateral clearances,
N is the number of directional lanes.

Factors used in these models are defined in highway capacity manual [3].

2. For multi-lane highways:

The service flow rate for level of servive i for the multi lane highway can be determined in the TPP-program from the following model:

$$SF_i = C_j \left(V/C \right)_i * N * F_W * F_{HV} * F_P * F_E \, ,$$

where:
F_E = factor of adjustment for the type of multilane highway and development environment, and

$$F_{HV} = \frac{1}{1 + P_t(E_t - 1) + P_B(E_B - 1) + P_r(E_r - 1)} \, .$$

Parameters used in these models are defined in highway capacity manual [3].

3. For rural two-lane highways:

Two-lane highways are defined as 2-lane roadways with one lane available to traffic in each direction. The service flow rate for level of servive i for the two-lane highway can be determined in the T.P.P-program from the following model:

$$SF_i = 2800 \left(V/C \right)_i * F_d * F_W * F_{HV} \, ,$$

where:
F_d is the an additional adjustment factor for the non ideal directional distribution of traffic.
where:

$$F_{HV} = \frac{1}{1 + P_t(E_t - 1) + P_B(E_B - 1) + P_r(E_r - 1)} \, .$$

Parameters used in these models are defined in highway capacity manual [3].

TPP can evaluate different transportation planning environmentally. It applies the following model to estimate the expected carbon dioxide (CO_2), methane (CH_4), and nitrogen oxide (NO_2) of a certain transportation scenario [4]:

$$Q = \left(q_{m.CO_2} + q_{m.CH_4} + q_{m.N_2O} \right) * TV_m$$

where:
Q is the total CO_2 and CO_2 -equivalent emissions in *kg/year,*
$q_{m.CO_2}$ is the CO_2 greenhouse gas emissions from transport mode m in *kg* CO_2 */pass.km* for passenger transport or *kg* CO_2 */ton.km* for freight transport,
m is the transport mode (car, bus, train, truck, tram)
$q_{m.CH_4}$ is the CO_2-equivalent emission from CH_4 (methane) in *kg CO_2-equivalent/ pass.km,*
$q_{m.N_2O}$ is the CO_2 -equivalent emission from N_2O (nitrous) in *kg* CO_2*-equivalent/ pass.km,*
TV_m is the transport volume, in *pass.km* or *ton.km,*

$q_m, ch_4 = a_m, c_{h4} * b_m * F_1 * F_2 * e_{CH4}\ C_m$
$q_m, N_2O = am, N_{2O} * F_1 * F2 * e_{N20} / C_m$

where:
a_{CO_2} is the factor for calculation of CO_2 emissions from primary energy consumed in *Kg* CO_2/MJ,
b_m is the specific primary energy consumption in *MJ/veh.km,* and
C_m is the occupancy rates.
F_1 & F_2 are the factors present behavior of car driver and status of transport mode (life time for car, bus and truck), and

$q_m, C_{H4} = a_m, C_{H4} * b_m * F_1 * F_2 * e_{CH4} / C_m$
$q_m, N_2O = a_m, N_2O * b_m * F_1 * F_2 * e_{N2O} / C_m$

where:

a_{CH_4} is the factor for calculation of CH_4 emissions in kg CH_4/MJ,

a_{N_2O} is the factor for calculation of N_2O emissions in kg N_2O /MJ,

e_{CH4} is the coefficient to convert CH_4 to CO_2-equivalent emissions, and

e_{N2O} is the coefficient to convert N_2O to CO_2-equivalent emissions.

Parameters used in these models are defined in [4]. The TPP program can also estimate the mean noise level produced from railway and road transport systems. For railway transport systems, the program applies the following model:

$$L_{m,e} = 10 \log \left\{ \sum ;10^{0.1(C+D_v+D_b+D_\ell+D_s)} \right\} + D_t + D_{br} + D_{cv} + D_{cu}, \quad (1)$$

where:

$L_{m,e}$ is the mean noise level of the running trains with different types (i), and for a railway track (j) in dB(A), measured at a distance of 25m from the track center line, and at a height of 3.5m above the rail level at a certain time period,

C is the constant, equal to 51 according to the German specification,

D_V is the Effect of type of vehicle (locomotive & cars),

D_b is the effect of type of brake , model (2),

D_S is the effect to running speed , model (3),

D_e is the effect of number of trains and train lengths, model (4),

D_t is the correction due to type of track,

D_{br} is the correction due to existence of bridge,

D_{cr} is the correction due to road crossing, and

D_{cu} is the correction due to existence of curves,

$$D_b = 10 \ \log\left(5 - 0.04 \ P_b\right), \quad (2)$$

where:

P_b is the percentage of vehicles provided with disk brakes.

$$D_S = 10 \log (0.1 \ V), \quad (3)$$

where V is the permissible train speed in km/h.

$$D_l = 10 \log (0.01 \ l), \quad (4)$$

where l is the sum of lengths of all trains class (i) running at one hour.

Parameters and corrections for noise model are identified in [5].

For road transport systems, the following model can be used to estimate the mean noise level $L_{m,e}$ (measured for a day 6-22 hours or a night 22-6 hours):

$$L_{m,e} = L_m^{(25)} + L_P + L_C + L_g + L_V + L_S + L_W ,$$

where:

$L_{m,e}$ is the mean noise level for a day or night in dB(A),

$L_m^{(25)}$ is the mean noise level in dB(A), measured at 25m distance from the middle of the nearest lane, and at a height of 0.50 m from the road surface for a speed of 100km/h, and asphalt pavement roads,

$L_m^{(25)}$ = 37.3 +10 log {Q (1 + 0.082 P)},

Q is the traffic volume in pcu/h,

P is the percentage of heavy traffic,

L_P is the correction due to pavement type in dB(A),
= 0, for asphalt pavement (flexible pavement),
= +1, for concrete roads (rigid pavement).

L_C is the correction due to traffic signal in dB(A). It depends on the distance between the measured point and the center line of the road crossing,

L_C = +3 dB(A) if distance to road crossing = 0 ~ 40m,
= +2 dB(A) if 40m < distance to road crossing ≤ 70m,
= +1 dB(A) if 70m < distance to road crossing ≤ 100m,

L_g is the correction due to road gradient in dB(A).

L_g = 0.6 * |g| - 3 for g > 5%

L_g = 0 for g ≤ 5%,

where:
g = road gradient in %,
L_V is the correction due to speed in dB(A), it can be determined from the following model:

$$L_s = L_{car} - 37.3 + 10\log\left[\frac{100 + (10^{0.1D} - 1)P}{100 + 8.23P}\right]$$

$$L_{car} = 27.7 + 10\log\left[1 + (0.02 * Vcar)^3\right]$$

$$L_{truck} = 23.1 + 12.5\log(V_{truck})$$

$$D = L_{truck} - L_{car}$$

where:
V is the traffic speed (km, hr)
P is the percentage of heavy traffic,
L_S is the correction in dB(A) due to distance between source and receiver,

$$L_S \; 15.8 - 10\log(S) - 0.0142(S)^{0.9}$$

S is the distance in m between source and receiver in m ,
L_W is the correction due to ground and weather condition in dB(A), where:

$$L_W = -4.8\, e^{-\left(\frac{hm}{S}\left(8.5 + \frac{100}{S}\right)\right)^{1.3}}$$

$$h_m = 0.5(h_1 + h_2)$$

h_1= height in m of source above pavement level.
h_2 is the height in m of receiver above pavement level.

5. Case study

The TPP-program has been applied for the GBA. Beirut the capital and largest city of Lebanon, covers about 67 square *Km* and lies on the mediterranean sea east of the Lebanon Mountains. The number of population reached 1.16 Million in 1994 (about 30% of the population live in Libanon). For years, the city ranked as one of the most important ports in the eastern mediterranean, handling a great volume of trade to and from the nearby countries of Syria, Iran, and Iraq.

With respect to population, certain centers such as Hamra, Verdan, Marlias and others attract higher densities. Fig. 4 shows the population distribution of zones of GBA.

Housing can be classified in to four sectors:

- Southern suburbs to the air port along the North Coastal corridor and on the hills till Bikfaya and Broumane.
- Industrial centrals, along the sea from Qurantine Harbor till Antellias and along the Beirut periphery.
- Commercial centers mainly at north along the high way.
- Schools and universities spread over the whole area.

The highest density of population is in Municipal Beirut and equals 78000 inh/sq.km, while the lowest is in the outer suburb and equals 8000 inh/sq.km [6].

2.7, 71% of the transportation demand in GBA is covered by private car. The bus has a share of 19% of this demand and the taxi has 10%.

The T.T.P-program is applied for the GBA. Orgin-Destination matrix for the year 2022 as an output for this program is illuatrated in table 1.

Sample of the output of the program for the network evaluation is shown in table 2.

Sample of the output of the program for the economic evaluation of a railway system is represented in table 3.

To improve the transport system in GBA, two strategies are investigated, namely, Trend scenario (Do-Nothing scenario) and Authorized Master Plan scenario.

The trend scenario supposes that no improvement for transport systems will be done ("Do-Nothing"). This means no measures may be performed for the next 20 years, but different energy sources for transport modes may be used. For this scenario, calculations are made for three different modes running on the whole network, namely:

- Private cars using petrol fuel (85% of the transport demand), m_1
- Taxis using electric energy (10% of the demand), m_2
- The mini-bus system using petrol fuel (5% of the demand), m_3

Table 1
O-D matrix of GBA for target year 2022
ODT :=

	1	2	3	4	5	6	7	8	9	10	11	12
1	9069	3396	2424	3374	1769	1524	909.61	563.8	657.44	608.82	268.76	211.28
2	3638	7848	4156	1787	2017	1084	796.29	597.75	522.58	479.5	247.52	213.23
3	3249	5196	26260	2139	3861	1614	1248	1257	859.86	796.48	450.8	449.99
4	3659	1810	1734	7194	1752	2207	1208	550.05	677.99	679.62	296.35	202.27
5	1360	1448	2221	1244	12000	1019	1265	1298	429.8	464.44	382.32	302.27
6	1656	1101	1318	2212	1431	9201	1197	537.47	937.9	1282	365.87	211.22
7	842.22	689.74	870.39	1033	1512	1022	2993	454.4	296.54	360.64	286.31	139.96
8	522.33	519.01	884.07	470.46	1539	459.18	452.8	4088	205.04	229.23	239.99	272.98
9	319.05	231.74	307.21	297.49	264.04	415.85	154.46	109.13	4200	357.74	64.59	49.42
10	645.54	476.62	642.3	664.95	628.75	1251	409.87	260.74	763.59	4150	183.53	111.6
11	392.36	339.21	504.13	398.54	317.12	487.49	441.92	366.97	183.63	246.88	1319	130.24
12	284.95	270.41	468.27	251.37	510.73	259.99	198.87	384.14	126.82	138.57	121.62	1998

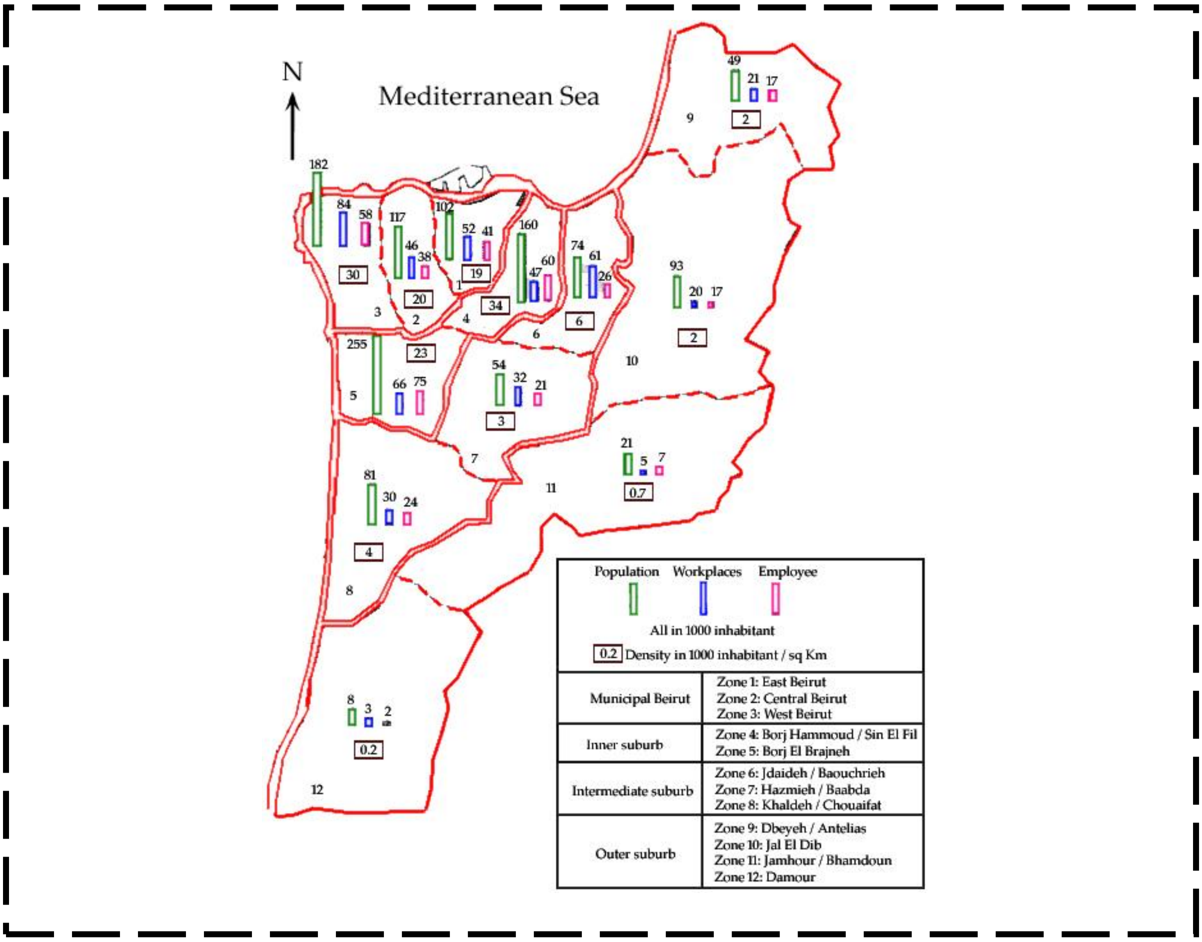

Fig. 4. Administrative internal zones of GBA and the population distribution.

Table 2
Input and output of the third module for GBA

Link		Flow (PCU/hr)	Capacity	LOS	Percent delay
14	15	2043	4200	B	32.5
15	14	802	4200	A	10
15	16	2045	4200	B	32.5
16	15	922	4200	A	10
16	23	3026	4200	C	52.5
23	16	559	4200	A	10
23	30	3264	4200	C	52.5
30	23	559	4200	A	10
30	33	1029	4200	A	10
33	30	559	4200	A	10
33	48	1029	4200	A	10
48	33	1257	4200	A	10
48	52	2424	4200	B	32.5
52	48	967	4200	A	10
52	54	2424	4200	B	32.5
54	52	2045	4200	B	32.5
54	101	2424	4200	B	32.5
101	54	5389	4200	F	100
101	99	5138	4200	F	100
99	101	930	4200	A	10

Table 3
Output of TPP for the economic evaluation of a railway system

RESULTS

HEAD WAY (PEAK HOUR) = headwaypeak = 8.1 minutes
HEAD WAY (OFF-PEAK HOUR) = headwayoffpeak = 10.125 minutes

ROUND TRIP TIME = roundtriptime = 2.15 hours

TRAIN OPERATING
HOURS PER DAY = totaldailytrainoperatinghours = 238.889 hours

FLEET SIZE = actualfleetsize = 141.564

TOTAL CAPITAL COSTS = TOTALCAPITALCOSTS = 282.751 us $ mil

TOTAL ANNUAL CAPITAL COSTS = totalcapitalcost = 20.776 us $ mil

TOTAL ANNUAL OPERATING
COSTS = totalannualoperatingcosts = 27.204 us $ millions

TOTAL ANNUAL COSTS = totalannualcosts = 47.979 us $ millions

COST PER PASS.KM = costperpasskm = 0.106 us $

COST PER PASS KM IN CASE OF SHORT FALL IN DEMAN
INCREASE IN CAPITAL COSTS = costperpassengerkm = 0.17 us $

$$\textbf{Total Emissions} = N = \begin{pmatrix} 1.164\,10^{10} \\ 1.635\,10^{7} \\ 3.694\,10^{6} \\ 1.281\,10^{10} \end{pmatrix} \begin{matrix} \text{KG CO2/YEAR} \\ \text{KG CH4/YEAR} \\ \text{KG N2O/YEAR} \\ \text{KG (CO2\&CO2-equivalent)/YEA} \end{matrix}$$

m(i) gives the emissions from system i

$$m(1) = \begin{pmatrix} 1.078\times 10^{10} \\ 1.515\times 10^{7} \\ 3.421\times 10^{6} \\ 1.187\times 10^{10} \end{pmatrix} \quad m(2) = \begin{pmatrix} 8.457\times 10^{8} \\ 1.189\times 10^{6} \\ 2.685\times 10^{5} \\ 9.313\times 10^{8} \end{pmatrix} \quad m(3) = \begin{pmatrix} 1.233\times 10^{7} \\ 1.733\times 10^{4} \\ 3.915\times 10^{3} \\ 1.358\times 10^{7} \end{pmatrix}$$

Fig. 5. Quantities of emission produced from trend scenario.

The Authorized Master Plan scenario is supposed to contain [7]:

- A large scale of the road network (improvements and new construction),
- Powerful public transport.
- The public transport system in this scenario consists of:
- A regional line from Damour to Jounieh
- Two metro lines, namely the East-West line from Ras Beirut to Nahr El Mout and the North-South line from the Airport to St. Michel terminal.
- Three bus lines, namely, American University of Beirut to Barbir, Ouzai to Beirut Port, and Soltan Hussain to Nahr El Mout.

The results of the first scenario can be summerized as:

- High volume-to-capacity ratio of most links of the road network (> 1.0)
- Low average speed (15 km/hr)
- High delays (> 95%).
- Large quantities of fuel consumption and pollution.

The quantities of emission produced from trend scenarios are illustrated in fig. 5.

Calculations for Athorized Master Plan Scenario are made for five different modes running on the transport network. These are:

- Private cars using petrol fuel (35% of the transport demand), m_1.
- Taxis using electric energy (10% of the demand), m_2
- The mini-bus system using petrol fuel (5% of the demand), m_3
- The bus system using petrol fuel (25% of the demand), m_4
- The rail system using electric energy (25% of the demand), m_5.

The public transport system in this scenario consists of:

- A regional line from Damour to Jounieh.
- Two metro lines, namely the East-West line from Ras Beirut to Nahr El Mout and the North-South line from the Airport to St. Michel terminal.
- Three bus lines, namely, American University of Beirut to Barbir, Ouzai to Beirut Port, and Soltan Hussain to Nahr El Mout.

The result of the second scenario indicates:

- A reduction of about 20% of the annual energy demand for the transport sector
- A reduction of the volume-to-capacity ratio of the road network
- An improvement of the Level Of Service (LOS) of the road network
- An increase of the average speed (36 *Km/hr*) on the urban road network
- A reduction of about 50% in greenhouse emissions

The quantities of emissions produced from this scenario are represented in fig. 6.

6. Conclusions

Along with social, economic, and cultural growth in developing countries, the need of people and goods for movement increases. And when this is not met with an increase in road

$$\textbf{Total Emissions} = \begin{pmatrix} 5.459\times 10^{9} \\ 7.62\times 10^{6} \\ 1.721\times 10^{6} \\ 6.007\times 10^{9} \end{pmatrix} \begin{matrix} \text{KG CO2/YEAR} \\ \text{KG CH4/YEAR} \\ \text{KG N2O/YEAR} \\ \text{KG (CO2\&CO2-equivalent)/YEAR} \end{matrix}$$

m(i) gives the emissions from system i

$$m(1) = \begin{pmatrix} 4.44\times 10^{9} \\ 6.241\times 10^{6} \\ 1.41\times 10^{6} \\ 4.889\times 10^{9} \end{pmatrix} \quad m(2) = \begin{pmatrix} 8.457\times 10^{8} \\ 1.189\times 10^{6} \\ 2.685\times 10^{5} \\ 9.313\times 10^{8} \end{pmatrix} \quad m(3) = \begin{pmatrix} 1.233\times 10^{7} \\ 1.733\times 10^{4} \\ 3.915\times 10^{3} \\ 1.358\times 10^{7} \end{pmatrix}$$

$$m(4) = \begin{pmatrix} 1.233\times 10^{8} \\ 1.733\times 10^{5} \\ 3.915\times 10^{4} \\ 1.358\times 10^{8} \end{pmatrix} \quad m(5) = \begin{pmatrix} 3.701\times 10^{7} \\ 0 \\ 0 \\ 3.701\times 10^{7} \end{pmatrix}$$

Fig. 6. Quantities of emission produced from the Authorized Master Plan scenario.

areas, and public transport facilities, many problems arise such as traffic congestion, bad levels of service, air, and noise pollution.

All these problems have effect not only on the economics of the country but also on the health of people and their production ability.

This paper deals with the transportation planning process in developing countries. A computer program, namely Transportation Planning Process TPP, has been developed. It has been programmed with the help of “Math-CAD 2001 Professional”. This program contains the main elements of a transportation planning process such as:

- Socio-economic data forecasting.
- Trip generation and attraction.
- Trip distribution.
- Modal split.
- Trip assignment and network evaluation.
- Environmental assessment.
- Economic analysis.

An application has been performed on the Great Beirut Area (GBA). The transport strategies for GBA such as trend scenario and authorized master plan scenario have been introduced.

The result of the first scenario indicates the following facts:

- High volume-to-capacity ratio, namely > 1, for most links of the road network which indicates a Level Of Service (LOS) of “F”.
- Low average speed on the road network, namely < 15 km/hr.
- High percentage of delay, namely > 95%.
- Large quantities of fuel consumption and pollution.

This means that reviewing the existing transport plan of GBA is a must. The new plan should be developed towards a comprehensive transport planning that satisfies travel demand, saves energy, and reduces harmful emissions and other adverse environmental effects.

The Authorized Master Plan scenario contains a large scale of the road network and a powerful public transport systems. The result of the second scenario for GBA indicates the following facts:

- A reduction of about 20% in the annual energy demand for the transportation sector can be achieved.
- A reduction of the volume-to-capacity ratio and an improvement of LOS.
- A higher average speed (36 *Km/hr*) on the urban road network.
- Reduction of about 50% in greenhouse emissions.

This scenario requires great investment costs.

Finally, the TPP program is simple and requires a minimal amount of data. Therefore, it is very useful to apply this program for developing countries.

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